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Methods For Measuring Vegetation Changes on Nevada Rangelands

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SUMMARY AND RECOMMENDATIONS

Frequency Sampling

A frequency sampling procedure was investigated because presence or absence is one of the most stable characteristics of vegetation. Evaluation of trend in range condition on key areas should be based, at least partially, on changes in % frequency. This method is also easy, fast, objective and repeatable. Human decisions are limited to species identification and to whether or not the plant is rooted within the frame.

Transect-quadrat sample plans were developed to yield the lowest cost for a specified variance or vice versa. Frame sizes that would provide precise information concerning the greatest number of important species were developed. The frequency sampling method was compared with other methods that might be valuable. The best method or methods for a given vegetation type were recommended.

A field guide was written on the procedures and sampling equipment for this method. Recommendations for proper sample plans, appropriate frame sizes, and number of samples for proper frequency samplings were made.

Oblique Ground Photography

An oblique ground photographic system was investigated with the camera 6-ft from the plot center and 54-inches above ground level. Two cameras were mounted side-by-side and 6-inches apart for stereo coverage. Cover, height, and density were extracted both on the ground and on the photos for correlations between the two. Time was kept to find the most efficient method for the results obtained.

Several conclusions were reached after analyzing the data obtained using the BLM trend procedure in the field and a method whereby the same measurements were made from oblique stereo photographs.

1. A single 5-ft^2 plot is inadequate as a basis to estimate range trend. A change in one small plot is not necessarily indicative of the same change over a large area.

2. Stereo-pair photographs taken from any angle are of great value in species identification and in evaluating data important for determining range condition and trend. If no measurements are to be taken from the photographs, a stereo image can be produced by simply moving the camera a few inches to one side and taking a second photograph.

3. Accurate species identification from photographs is possible only with color film.

4. Cover measurements of individual plants taken from oblique photographs are extremely unreliable.

5. Time of year plays an important part in identifying plant species from photographs. Accuracy of species identification can be increased by choosing a time when any two species appear least alike in color and/or growth form.

Vertical Ground Photography

A vertical photographic method consisted of mounting two cameras 1-ft apart in tandem and 100-inches directly above the plot. Cover and density were obtained both in the field and on the photos for correlation between the two. Time was recorded to evaluate efficiency.

Results indicate that:

1. Species cover and density can generally be obtained and is similar to that obtained by the field method.

2. A permanent record is available of the vegetation for future rechecking or reference.

3. A considerable savings in field time is realized by the vertical photographic technique.

4. A variable height tripod for different plant communities would be advantageous.

5. This method would be a good supplement to large scale aerial photography.

70mm Large Scale Aerial Photography

Low-level, large scale 70mm color aerial photography was obtained from 6 habitat types in Nevada with a Hulcher 70, Model 103 aerial camera. Scales ranging from 1:160 to 1:1960 were analyzed from May 27 to August 29. Color and color infrared film types were evaluated. A species identification key was developed for each study site using the following criteria: color, pattern, texture, size, relative number of plants, shadow and date of photography.

Several methods were used to obtain cover on aerial photos including planimeter, point, estimation and line intercept methods. Several other features such as litter, rocks, erosion features and animal signs were also observed and recorded.

The following conclusions were reached.

1. All tree species, most shrubs and some grasses and forbs can be accurately identified on 70mm large scale aerial photography.

2. Percent cover can be obtained from recognizable species on photographs in a significantly shorter time than conventional field methods using larger sample sizes.

3. Density (number of plants per unit area), as normally thought of, is impossible to extract from large scale photographs for most species.

4. Not all species can be identified on all dates, but the most prominent species can be identified on all dates.

5. A scale of 1:1,200 appears optimum for measurement of trees and large shrubs while a scale of 1:600 seems ideal for measurement of smaller species.

6. Both color and color infrared films are valuable for species identification.

7. Color infrared film is more valuable for litter detection and assessing relative health and vigor.

8. Color film is superior for detecting rocks, animal and erosion signs.

9. A savings in time and costs are incurred using aerial photography to gather certain types of information.

Vertical Ground Photography Combined with 70mm Large Scale Aerial Photography

The best photographic technique for range condition and trend evaluation we could devise is a multiple procedure which utilizes large scale 70mm aerial photography for sampling larger species while a variable height tripod is employed for sub-sampling the smaller grasses and forbs. Seedling counts can be made in the field or by yet another sub-sampling technique which might require a third photograph from possibly 18-inches above ground level in a carefully selected area or both. Neither aerial photography nor ground photography alone seems to provide an optimum solution for all cases.

From the research performed, the following recommendations are made for range condition and trend evaluation:

1. Fly two or possibly three key areas per allotment and obtain 70mm aerial photography at a scale of about 1:600 depending on the species encountered using Ektachrome infrared film. If a tree overstory is present such as mountain mahogany or pinyon and juniper, the photo scale may need to be increased to 1:1,000.

2. Select two ground photoplots within a homogeneous area using a pair of 70mm photos. The camera height of the ground photoplots is predetermined by the size and density of the understory vegetation.

3. Return to the office and either obtain or summarize the following measurements:

   a. Cover and density of shrubs and trees on 70mm prints.

   b. Cover and density of forbs and grasses on 35mm ground photographs.

   c. Estimates of litter, rock and bare ground on both the aerial and the ground photos.

   d. Seedling counts in the field when the ground photographs are taken.

   e. Relative health and vigor of plants subjectively evaluated on 70mm infrared film (more valuable as additional data becomes available).

   f. Animal tracks, burrows and other animal signs counted or estimated on the aerial photographs.

   g. Detect and possibly measure erosion signs such as rills and gullys on the aerial photographs.

4. Repeat this sampling procedure on a 5-year basis giving emphasis to allotments which appear to be changing or allotments which have had recent management changes. Sites that appear stable may only need to be rephotographed at 10-year intervals. The procedure should remain flexible to meet individual allotment needs.

Permanent markers can be established on each key area such as a white steel plate welded to the top of a steel post and placed at each end of a transect. The posts are used to check scale, guide the aircraft in succeeding flights, and used as reference for ground photoplots. The white plate is replaced each time the ground photography is performed.

Costs for the recommended procedures were:

1. 70mm infrared film costs $50 for 100-feet.

2. 70mm infrared film costs $50 for 100-feet to be developed. (This provides nearly 500 frames or about 200 stereo pairs).

3. 70mm infrared prints are $1.50 per 8-inch x 10-inch print. (This cost can be foregone if an initial investment is made in equipment for stereoscopically viewing transparencies).

4. Airplane rental at $40 per hour.

5. 35mm prints cost 0.25 each or slightly more depending on where they are developed.

Each site to be photographed aerially is covered adequately with 10 feet of film and requires an average of 30 minute's flight time. We estimated that a stereo pair of aerial prints can be obtained on each key area for a total of $44 per key area not including the man hours required for this operation. Two men, one as pilot and the other as camera operator, can easily perform all the aerial photography on a district or maybe several districts. With the aid of interpretation keys, technicians with the advice of Range Scientists can extract the bulk of the information from both aerial and ground photography.

INTRODUCTION

Nevada has several million acres of rangeland with many different vegetation types. These lands are managed for production of livestock forage, food and cover for wildlife, water, wood products and recreation. To manage these lands properly, an awareness and understanding of changes in the vegetation in relation to a standard are necessary. Changes detected and correlated with a certain level of vegetation utilization can form the basis for alterations in management plans.

Many methods have been used with varying degrees of success. Attempts have been made to adapt a single procedure to all vegetation types. This is normally not practical since a single technique will not provide data with high precision and repeatability on all vegetation types.

Trend surveys should make use of objective, adequate sampling and interpretation of range indicators. All procedures should be understood by both the range user and the range technician. A quantitative method developed for its ease of understanding coupled with statistical precision and ease of duplication will be a definite aid in the management of Nevada rangelands.

Procedures for determining the condition and trend of Nevada range vegetation have been investigated over a 6-year period (1964-1970) in three primary areas:

1. The measurement of range vegetation trend by frequency sampling.

2. Oblique and vertical, stereo ground photography for range condition and trend analysis.

3. 70mm low-level, large scale color aerial photography for range condition and trend analysis.

These studies were supported by the U. S. Department of the Interior, Bureau of Land Management and the Renewable Resources Center, University of Nevada Reno on a cooperative basis.

OBJECTIVES

1. To analyze the frequency sampling procedure proposed by Hyder *et al.* (1963) by:

   a. Developing transect-quadrat allocations for the frequency sampling procedure to yield the lowest cost for a specified variance or vice versa.

b. Developing frame sizes for the frequency sampling procedure that would provide precise information concerning the greatest number of important species.

2. To determine if measurements taken from ground-level oblique and vertical photographs could effectively be used to quantify range vegetation by:

   a. Determining the accuracy with which measurements of range vegetation may be made on photographs.

   b. Comparing the method outlined in the current Bureau of Land Management trend manual with measurements taken from photographs alone.

3. To determine if large scale color aerial photography can effectively be used to quantify range vegetation by:

   a. Developing a plant identification key to aid subsequent observers in identifying plant species.

   b. Determining if vegetation parameters such as cover and density can be measured on photographs to record vegetation changes.

   c. Identifying soil surface and erosion plus animal signs on photographs.

   d. Comparing the efficiency of aerial and ground photographic techniques in concert for gathering trend data.

LITERATURE REVIEW

Range Condition and Trend

Wooton (1908) recognized range condition as an important factor which could be read from the land. He stated that abundance of desirable range forage plants or of range weeds illustrates the past treatment of the grazing land and represents range condition.

Sampson (1919) is credited with the recognition of the need for range condition classes. He concluded that: "the most rational and reliable way to detect overgrazing is to recognize the replacement of one type of plant cover by another." Also, he concluded that grazing value of vegetation cover is highest where the cover represents a stage in proximity to the herbaceous climax and lowest in the type most remote from the climax. Sampson's classification system had four parts: first weeds, second weeds, mixed grass and weeds, and climax. These four classes correspond to the very poor, poor,

fair, and good rating which are now being used (Parker, 1954; Pickford and Reid, 1942).

Range condition is generally a dynamic situation. The change away from or toward desirable condition is referred to as "range trend." Trend is not only directional but has aspects of velocity, selectivity, and magnitude. Correct appraisal of condition is primarily a forage inventory, but the appraisal of trend allows the manager to see past mistakes and plan for the future (Bailey, 1945; Parker, 1954). Bailey (1945) states that "determination of trend is telling whether the range condition is being maintained, is improving or is deteriorating in relation to the most desirable condition."

Dyksterhuis (1949) studied condition and trend thoroughly and approached the matter from several directions, including an evaluation of plant vigor. Plant vigor is an important indicator of condition, but due to the complexity of its determination, it was abandoned. Vigor, nevertheless, is an indicator of trend in range condition and should not be forgotten.

Dyksterhuis (1949) presented a system of ecological classifications based on response to grazing. His classification system introduces the terms (1) decreasers, (2) increasers, and (3) invaders to describe the dominating vegetation of a plant community. "Decreasers" and "increasers" are considered species of relatively undisturbed climax communities, and "invaders" are non-climax species occurring on disturbed areas (Parker, 1954).

Frequency Sampling

Hyder *et al.* (1963) proposed frequency sampling for condition and trend on the basis that "characteristics of plant density and dispersion, as blended in frequency data, might be more appropriate for range-site-and-condition classification than plant cover." General frequency sampling techniques were explained in this paper, and appropriate sampling procedures for the *Artemisia arbuscula/Festuca idahoensis* association in southeastern Oregon were described.

Hyder *et al.* (1965) outlined the procedure for efficient frequency sampling on blue grama *(Bouteloua gracilis)* ranges in Colorado. He illustrated the advantages of the method and further explained the collection and analysis of frequency data.

Gleason (1920) stated that although frequency percentages might mean very little to a person unfamiliar with them, terms such as "common," "rare," or "abundant" are even more subjective and therefore less meaningful.

Kenoyer (1927) found that frequency is very useful for determining the homogeneity of a plant community. Hanson and Ball (1928) used frequency to evaluate two adjacent pastures which were grazed by livestock. They stated that the method promises to be valuable in connection

General key. All species from all sites were combined in one key. Several characteristics were used to separate similar species on different sites that did not appear together in the individual key. A few of the same species were present on more than one site. They may appear slightly different on various sites due to different environmental influences so slightly more encompassing characteristics were developed to adequately group these species. A general key for Doby Summit, Secret Pass, Ward Mountain, Mormon Mesa, Paine Springs and Duck Creek Basin sites can be found in Lorain (1970).

A Joint Committee of the American Society of Range Management and the Agricultural Board (1962) stated that repeat photographs taken over a period of several years would definitely show trend in range condition. They said, however, that photographic plots "are useful for illustrative purposes but in themselves do not provide a quantitative measure of the vegetation."

Claveran (1966) reported using Polaroid film in a 4 by 5-inch press camera to obtain immediate prints of photographs taken in desert grassland vegetation. Stereoscopic pairs were used to trace boundaries of range plants. The area covered by each plant was calculated using a transparent dot grid in which the number of dots had been determined by the formula described by Avery (1962).

In Australia, Wimbush, *et al.* (1967) successfully used color stereoscopy to measure meadow vegetation. They used a 35mm single-lens reflex camera, a 28mm wide-angle lens, and color transparencies, which were projected through prisms onto a glass table for stereo viewing.

Recently, Burwell and Bullock (1968) devised a method for obtaining vertical stereo pairs of range vegetation from a height of 8 feet 4 inches. The method involves moving a large tripod 2 feet between exposures. The prints are enlarged to a scale of 1:12, and the outline of each plant is traced onto mylar plastic. The area is then estimated using a grid of 100 squares per square inch. Large shrubs, such as big sagebrush *(Artemisia tridentata)* were avoided, since "plants under big sagebrush are not available to livestock, and therefore, should not be considered in range condition and trend" (Burwell, personal communication).

Aerial Photographic Techniques

Aerial photography has long been utilized by both foresters and range managers, but small scale (1:10,000 or smaller) black and white photographs have dominated the scene. The early photographs were used largely for locating objects in the field and drawing broad vegetation type maps (Harris, 1951; Park, 1955; Stoddart and Smith, 1955). Foresters have gone a step further and used aerial photographs for timber volume estimates, heights of trees, crown diameters and stand densities (Spurr, 1956, 1960; Garrard, 1951; Avery, 1960, 1968). Identification of individual species, or even plant communities, was largely not possible on small scale black and white photography. The need for identification and quantification of individual plant species has led to the procurement of large scale aerial photography to enhance ground resolution.

Color film is an additional tool to aid identification of features on an aerial photograph. About 200 shades of gray can be distinguished on black and white photography. Most humans, however, cannot discriminate this many shades. In contrast, humans have the capability of discriminating between an almost limitless number of colors due to the three color

dimensions; hue, value and chroma. Color infrared film has added even another dimension to enhance the identification of objects on photographs, especially live vegetation. Color infrared film is sensitive to wavelengths beyond the visible portion of the electromagnetic spectrum from 700 to 900 nanometers. Object identification has been immeasurably increased by employing both of these film types simultaneously (Colwell, 1956).

Initiation of research using large scale (1:2,000 or larger scale), color aerial photography to identify species and quantify vegetation on rangelands has been limited until very recently. One of the problems encountered with low-level photography is that a very small area is covered by the stereo overlap portion of adjacent photographs. Aldrich, *et al.* (1959) suggested a photo sampling scheme with subsamples of large scale photography selected throughout the total area involved from smaller scale photography.

Heller, *et al.* (1959) evaluated several camera systems for image motion at low altitudes. They found the 70mm Hulcher camera to be superior for large scale photography at shutter speeds of 1/1,000 second or faster. Aldrich, *et al.* (1959) indicated that an electronic intervalometer can be used to trigger four exposures per second to obtain 60% overlap using a 70mm camera with 6-inch focal length lens and the plane flying 100 miles per hour at 300-ft above the terrain. This technique appeared to allow an adequate assessment of the before and after effects of an aerial spray test on white pine in New York State to eliminate bark beetle infestations.

Aldrich (1966) proposed that 70mm cameras were ideal for low-level aerial photography due to fast shutter speeds and rapid film advance. Other important components making them desirable are: their relatively low cost, their small size and light weight allow versatility that is valuable at low altitudes and their lenses can be quickly and easily changed. Other factors are their narrow angles of view reduce effects of parallax, the film is easy to process with consistent results and films can be studied stereoscopically in the roll without cutting. Aldrich (1966) specified that tree species identification for all trees is 90% using a scale of 1:1,584 on color film. Crown closure of tree species was also measured accurately on aerial photographs. Aldrich suggested that 70mm photography might be extended to range management by employing some of the same principles developed for forestry.

One of the initial studies involving the use of 70mm large scale color aerial photography on rangelands was initiated by Carneggie and Reppert (1968). They photographed five different vegetative types on three dates during the 1967 growing season. Two cameras were triggered simultaneously, one with color Anscochrome film and the other with color infrared film. Significant range features were marked on the ground for later identification on the photographs.

Carneggie and Reppert (1968) indicated that the color of a shrub as seen on a color photograph is represented by a combination of foliage

color, shadow, and soil background. The infrared reflectance of a plant is governed by (1) species, (2) the quantity and compactness of green foliage, (3) the moisture content of the leaves (Weber and Olson, 1967), (4) phenological development of plants, (5) disease status of the foliage (Colwell, 1956), (6) plant cell anatomy, (7) structural characteristics of the mesophyll (Colwell and Olson, 1964), and (8) photosynthetic activity.

Carneggie and Reppert (1968) further proposed that phenological changes of a plant over the season may be valuable for species identification.

Driscoll and Reppert (1968) attempted to develop a dichotomous plant identification key using color, foliage pattern, texture, relative size, shape and shadow of a species as the major discriminating criteria. They are also attempting to use a microdensitometer to analyze photographs for community characteristics which would be correlated with ground truth data.

STUDY SITES

A total of 17 different study sites representing the major vegetation types in Nevada have been investigated over the past 6-years (Table 1, Fig. 1). All the vegetation types were not investigated with each technique due to time and cost constraints. The sites range from north of Elko to near Las Vegas (Fig. 1). The specific site locations and descriptions can be found in the theses of Wilkie (1966), Kipping (1968) and Lorain (1970).

METHODS

Frequency Sampling Procedure

The primary hypothesis of this phase of the study was that frequency sampling could be developed into a fast objective method for accurately determining vegetation trend. Two additional supporting hypotheses were maintained: that certain transect-quadrat allocations were most efficient in terms of time and variance, and that certain frame sizes would sample more species efficiently. The final hypothesis was that there can be lower data variation with frequency sampling than with methods currently employed.

Appropriate quadrat sizes were developed by testing a wide selection of frames; 30, 20, 15, 12, 10, 6, 5, and 3 inches square. Each frame size was used, regardless of the result, on all communities until a better understanding of appropriate quadrat size was gained.

Frames were made with one open side to facilitate placement (Fig. 2). Each frame was marked to provide nested frequency frames. Microplots

Table 1. A list of the plant associations studied on at least one phase of the project.

Artemisia tridentata/
Oryzopsis hymenoides

Artemisia tridentata/
seral

Artemisia tridentata/
Agropyron spicatum

Artemisia arbuscula/
Bromus tectorum

Artemisia arbuscula/
Poa secunda

Artemisia nova/
Poa secunda

Artemisia longiloba/
Poa secunda/
Festuca idahoensis

Sarcobatus baileyi
Oryzopsis hymenoides

Artemisia spinescens/
Atriplex confertifolia

Chrysothamnus viscidiflorus/
seral

Eurotia lanata

Larrea tridentata/
Ambrosia dumosa

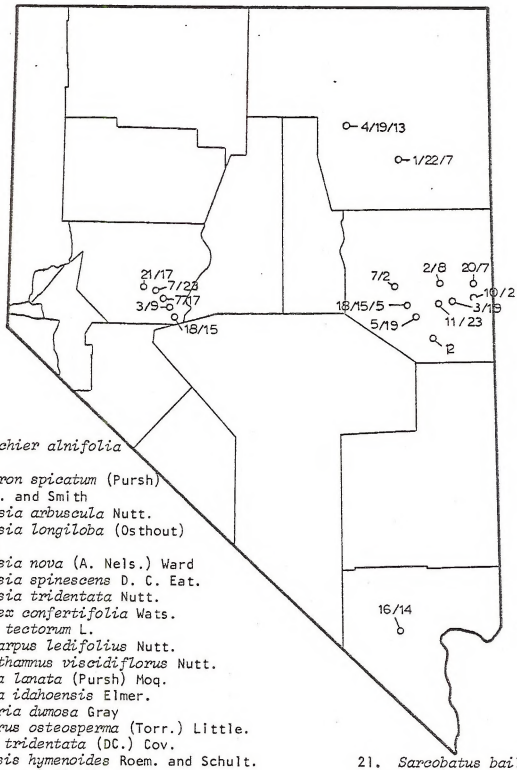
Amelanchier alnifolia/
Symphoricarpos longiflorus/
Artemisia tridentata

Cercocarpus ledifolius/
Agropyron spicatum

Purshia tridentata/
Artemisia tridentata

Pinus monophylla/
Juniperus osteosperma

Pinus monophylla/
Juniperus osteosperma/
Artemisia nova



1. *Amelanchier alnifolia* Nutt.
2. *Agropyron spicatum* (Pursh) Scribn. and Smith
3. *Artemisia arbuscula* Nutt.
4. *Artemisia longiloba* (Osthout) Beetle
5. *Artemisia nova* (A. Nels.) Ward
6. *Artemisia spinescens* D. C. Eat.
7. *Artemisia tridentata* Nutt.
8. *Atriplex confertifolia* Wats.
9. *Bromus tectorum* L.
10. *Cercocarpus ledifolius* Nutt.
11. *Chrysothamnus viscidiflorus* Nutt.
12. *Eurotia lanata* (Pursh) Moq.
13. *Festuca idahoensis* Elmer.
14. *Franseria dumosa* Gray
15. *Juniperus osteosperma* (Torr.) Little.
16. *Larrea tridentata* (DC.) Cov.
17. *Oryzopsis hymenoides* Roem. and Schult.
18. *Pinus monophylla* Voss.
19. *Poa secunda* Presl.
20. *Purshia tridentata* (Pursh) DC.
21. *Sarcobatus baileyi* (Cov.) Jeps.
22. *Symphoricarpos longiflorus* Gray.
23. Seral community

Fig. 1. Location of study sites with dominant plant species included.

Fig. 2. A 12-inch square frame showing the 3- and 6-inch prongs for dual sampling (nested frames) and rooted presences for a grass and big sagebrush.

were randomly located along a 100-ft baseline which served as the macroplot.

Reading the quadrats consisted of two very simple decisions: species identification and noting presence or absence within the frame.

Sampling theory was utilized to determine the optimum allocation of quadrats to transects and to establish the cost of obtaining a specified variance or the variance obtainable for a specified cost.

Range scientists from the Bureau of Land Management assisted in clarifying the procedures to make them more understandable. These scientists went to the field to obtain a frequency sample after reading the write-up and the problems encountered were clarified in improved write-ups (Appendix B).

Oblique Ground Photography

To facilitate measurements of vegetation with oblique photographs, a standard height, angle and distance had to be established for camera stations. A camera height of 54 inches from ground level, a ground distance of 6 feet from plot center, and an angle such that the center of the photograph coincided with the plot center proved most efficient. Higher angles caused problems with focusing and framing the photographs.

Two cameras were mounted side-by-side with a 6-inch stereo base or distance between the lenses. This distance provided adequate stereo images without excess exaggeration.

As a comparison with the BLM trend procedures, the "ground truth" measurements were taken according to the recommendations outlined by the Bureau. Cover measurements were made by determining two diameters of each perennial plant and calculating the area by the ellipse formula: $A=\pi ab$; where a and b are lengths of the major and minor radii. Measurements of basal area, grasses and forbs were taken one inch above ground level. Shrubs were measured for area of live crown. Density counts were made for each species which could not be measured in terms of cover. Height measurements were taken for each plant for which cover was measured.

Since it was impossible to measure two diameters of a plant from oblique photographs, "cover" measurements from the photographs consisted of a single diameter, measured parallel to the front edge of the plot frame. Density counts and height measurements were made from the photographs according to the same rules used in the field procedure. The measurements were made with a dial caliper, graduated in thousandths (.001) of an inch. These measurements were corrected to correspond with field measurements, using scale adjustment factors calculated for various portions of the photograph.

To make statistical comparisons of the two methods, and as a means of evaluating the need for plot replication, eight 25-ft^2 microplots were located systematically along a 100-ft baseline within each plant community.

Correlation analyses were made on field and photo measurements of 14 plant communities. These communities presented a number of sampling problems encountered in Nevada. At 6 of 14 sites, exclosures were available, and a second macroplot was sampled inside to test the sensitivity of each method to like vegetation in unlike condition classes.

Vertical Ground Photography

A vertical, stereo photographic method employing two 35mm cameras equipped with 28mm lenses and mounted 1-ft apart was tested. The cameras were mounted 100-inches above the ground on a tripod over a 25-ft^2 plot frame. Both cameras were fired simultaneously and stereo pairs of Kodacolor prints were obtained on each plot (Fig. 3).

The field procedure consisted of systematically locating 20 plots on each site. Cover and density were recorded for each species when the photographs were taken. The procedures followed were those recommended by the BLM trend procedure manual.

In the office, color prints were arranged beneath a mirror stereoscope. A mylar overlay was placed over one photograph of the stereo pair. Each plant was carefully outlined on the mylar using a rapidograph (00) while viewing them in stereo. After this, the mylar was placed on graph paper (20 x 20 squares per square inch), the area of each plant figured by counting squares and a percent cover computed. Density was determined by counting the plants outlined.

Simple correlations were computed between field and photographic data. Time required for both office and field procedures were recorded to determine the more efficient method.

70mm Large Scale Aerial Photography

Low-level, large scale 70mm color aerial photography was obtained from six habitat-types in Nevada with a Hulcher 70, Model 103 aerial camera equipped with a Schneider-Xenotar F2.8 lens. Various scales ranging from 1:160 to 1:1960 and dates ranging from May 27 to August 29 were examined in search of an optimum. Both color and color infrared film types along with prints and transparencies were analyzed to make interpretations and measurements.

Several types of ground truth markers for identification of objects, measurement of scale and guiding the aircraft were tested. Round paper plates and poster paper were initially used to mark species, but were later replaced by triangular, shaped sections of poster paper. Large

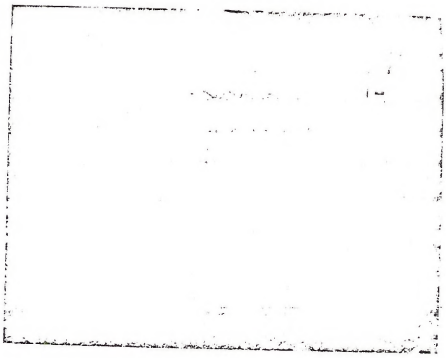


Fig. 3. 3.5- x 5-inch Kodacolor print of the Doby Summit site showing *Chrysothamnus nauseosus* in the yellow and *Artemisia longiloba* in the gray.

plywood boards were used as scale markers until short segments of lath were substituted to overcome placement problems.

Transparencies were examined on a light table with a two to four power stereoscope and measurements were made with comparators. Prints were viewed beneath a reflecting mirror stereoscope and measurements extracted with a dial caliper.

Validity of species identification on aerial photographs was tested by positive identification in the field on mylar overlays. These same specimens were later identified on both color and color infrared prints and transparencies for comparisons with field identifications. Different dates and scales were also included.

A species identification key was developed for large scale color aerial photography on each study site. The differentiating characteristics evolved largely from observations made during the identification tests. Criteria employed were color, pattern (Fig. 4), texture, size, relative number of plants, shadow and date of photography. Different ground methods were utilized to measure the vegetation including a portion of a ground photographic sampling system to collect cover and density data.

Cover data were obtained from aerial photographs in four ways: the planimeter, point, estimation, and line intercept methods. Density was obtained by counting the plants within a sample area delineated on a photograph and was used to compare with field samples. Litter, rock, erosion features, animal signs and other detectable features were observed on the ground and compared with observations made on ensuing aerial photographs.

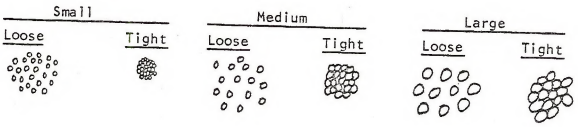
RESULTS

Frequency Sampling Procedure

Recommendations for proper sample plans, appropriate frame sizes, and number of samples necessary to adequately sample a range type are presented for all plant communities studied (Appendix B). This list includes many of the important range plant communities in the State. Two sample plans and frame sizes are suggested for the *Amelanchier alnifolia/Symphoricarpos longiflorus/Artemisia tridentata* plant community. If the community is fairly open, the square frame and appropriate sample plan are recommended; however, a community with several large shrubs, e.g., *Amelanchier alnifolia*, which are densely located, will probably be more easily sampled with the 6-ft diameter circular quadrat.

Frequency sampling procedures and sampling equipment were studied, and a field procedure handout was written and tested (Appendix B).

Small, medium and large clumpy pattern showing both loose and tight configuration.



Pattern showing foliage which appears to radiate out from a central point with the rays being coarse, medium or fine.

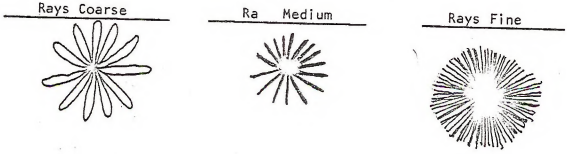


Fig. 4. Patterns

Oblique Ground Photography

Five of the 14 plant communities considered in this portion of the study had significant correlations on a large percentage of the characteristics measured (Table 2). These were: whitesage/black sagebrush; shadscale/galleta grass; bud sagebrush/shadscale; pinyon/juniper/black sagebrush; and the creosote bush/big galleta grass plant communities. In each case, success of the oblique stereo photo method was attributed to low percent cover, low plant density, relatively low-growing species, or a combination of these factors. All of these conditions allowed reasonably good visibility of the plots.

On each of the other nine plant communities studied, good correlations were obtained for one or more of the characteristics measured, but in general, results were poor.

The initial sample of eight macroplots per community was inadequate to obtain statistically reliable results on virtually all characteristics measured by either method.

Total time requirements for the two methods were quite similar, but the photo method required much less field time, generally considered most valuable by agency personnel.

Species identification was greatly enhanced when photographs were viewed stereoscopically. Stereo pairs better enabled the interpreter to distinguish between individuals of the same species.

Examination of photos taken by the BLM trend procedure and comparing them with photos taken by the stereo photo method indicated that the former method resulted in photographs of a different scale each time. This was a result of hand-holding the camera from a stepladder. The stereo pair method, on the other hand, incorporated a constant camera height and angle. This requirement resulted in photographs with a constant scale and allowed a single set of scale adjustment factors which were applied to all plots. With hand-held photography, separate adjustment factors were required for each plot, or for each photographer, since the height and framing of the plot within the viewfinder varies considerably.

Variation between interpreters was evaluated by two interpreters measuring or estimating vegetation parameters from the same plant community on the same photographs. As an added check, they were asked to measure and estimate the vegetation from a second plant community, along with a third interpreter. The two plant communities compared were the most simple (dryland greasewood/Indian ricegrass) and one of the most complex (big sagebrush/bluebunch wheatgrass) (Table 3).

Measurements taken by the interpreters were not always well correlated with the field data, but in general, the measurements were similar. Interpreter "C" was not well correlated with the other two people in the case of height measurements of the dryland greasewood/Indian ricegrass community. After working with this interpreter, it was found that he was measuring the height of plants from the front base of the plant, rather than using the stereo image to locate a point directly below the tallest part. When this difficulty was overcome, his measurements more closely resembled those taken by the other interpreters.

Table 2. Summary of correlation coefficients for field versus photo measurements on the plant communities.

Plant Community	Total Cover	Total Height	Total Density
Artemisia tridentata/Agropyron spicatum	.3467	.0866	.8291[b]
Artemisia tridentata/Agropyron cristatum	.3745	.5801	.7681[c]
Artemisia nova/Poa secunda	.4899	.5623	.4253
Artemisia longiloba/Festuca idahoensis	.7849[c]	.0322	.9290[a]
Sarcobatus baileyi/Oryzopsis hymenoides	.4441	.7508[c]	.9256[a]
Eurotia lanata/Artemisia nova	.7776[c]	.9071[a]	.8847[b]*
Eurotia lanata	.4470	.9176[a]	.3030
Atriplex confertifolia/Hilaria jamesii	.8034[b]	.9730[a]	.7015[c]*
Artemisia spinescens/Atriplex confertifolia	.9480[a]	.8793[b]	.9084[a]*
Purshia tridentata/Artemisia tridentata	.8090[b]	.3587	.5284
Amelanchier alnifolia/Symphoricarpos longiflorus/Artemisia tridentata	.0855	.4733	.1980
Cercocarpus ledifolius/Agropyron spicatum	.8946[b]	.4763	.5902[d]
Pinus monophylla/Juniperus osteosperma/ Artemisia nova	.8130[b]	.9761[a]	.9613[a]*
Larrea tridentata/Hilaria rigida	.8878[b]	.9135[a]	.6785[c]*

* Significant correlations for all 3 characteristics.

[a]Significant at P≤ .001
[b]Significant at P≤ .01
[c]Significant at P≤ .05
[d]Significant at P≤ .10

Table 3. Comparison of correlation coefficients from two widely different vegetative types, including correlations between interpreters and between field and photo measurements.

TYPE: *Sarcobatus baileyi/Oryzopsis hymenoides*

	Cover			Density			Height		
	A*	B	C	A	B	C	A	B	C
B*	.7660[c]			.8838[b]			.8627[b]		
C	.7681[c]	.6040[d]		.8724[b]	.9647[a]		.5102	.1558	
Field data	.4214	.4441	.6765[c]	.9873[a]	.9256[a]	.8989[a]	.6781[c]	.3787	.7508[c]

TYPE: *Artemisia tridentata/Agropyron spicatum*

	Cover		Density			Height		
	B	C	B	C		B	C
C	.9325[a]		.6855[c]			.6140[d]		
Field data	.3467	.5805	.8291[b]	.4268		.0866	.5379	

* Interpreter

[a]Significant at $P \leq .001$
[b]Significant at $P \leq .01$
[c]Significant at $P \leq .05$
[d]Significant at $P \leq .10$

The fact that measurements by various interpreters were similar to each other, but not to the field measurements, indicated that interpreters were all identifying and measuring the same things in the photographs. However, they were not able to detect everything in the plots from the photographs.

Variation between interpreters was not serious, because measurements made by different interpreters were quite similar. Also, a certain amount of variation between observers was noted in the field procedure. While not quantified, it was observed during gathering of field data that the two observers did not always agree on exactly how or where to measure an individual plant, particularly when that plant was only partially within the plot frame. It is improbable, therefore, that field measurements of the same plot by two different observers would always agree, any more than photo measurements by two different interpreters would.

Records kept of time requirements for each method on several plant communities are summarized in Table 4. The field method required more field time, but less office time than the photo method. The "summarization" time for both methods included time required for calculations, such as basal area or to correct for photo scale.

"Measurement" time for the photo method included time required to set up the stereoscope and align the photographs for stereo viewing, as well as the actual time required to measure the plants.

Generally, a complex community required more time, but in some instances, a complex community was measured in less time because the interpreter could clearly distinguish and measure only two or three species.

Vertical Ground Photography

Correlation coefficients were computed for each species on each site to show relationships between field and photo data. Density and percent cover values were considered. Data were analyzed to determine if a significant difference between the means for both percent cover and density at the 95 percent level of probability existed. Examples of these results appear in Tables 5-7.

Percent cover was computed accurately using photographs for medium-sized shrubs such as rabbitbrush, horsebrush, black sagebrush and smaller plants of big sagebrush and bitterbrush. Tall shrubs were difficult to measure accurately on the photographs since they appeared much larger on the photos than they really were due to their closer proximity to the camera lens than smaller plants. Correlation coefficients between field and photo data for most grasses were rather poor except at Mormon Mesa where big galleta, a large bunchgrass growing in a sparsely populated desert community, was easy to identify and measure accurately on the photographs. Correlation coefficients between field and photo data were low for other grasses primarily because many individuals grew beneath

Table 4. Comparison of time requirements (minutes/25 square foot plot) for the field and oblique stereo photo methods, including time required to set up and move equipment.

	Field Method			Stereo-Photo Method		
	Min.	Max.	Mean	Min.	Max.	Mean
Field	13	35	18	3	7	7
Office						
Measurement	-	-	-	5	40	25
Summarization	10	25	15	5	45	20
TOTAL	23	60	33	13	92	50

Table 5. Correlation coefficients between field and photo percent cover and density both outside and inside the Major's Exclosure.

Outside	1968 Field % cover	1968 Photo % cover	Correlation coefficient
Arno	2.2	2.2	.9264[2/]
Eula	11.9	9.9	.8737
Chvi	3.4	2.7	.9406
Orhy	.5	.6	.7297
Eriog	.4	.1	.6257
Phdi	.3	.2	.9992
Total	18.9	15.7	.9349

Outside	1968 Field density	1968 Photo density	
Arno	2	2	1.000
Eula	25.2	20.7	.9485
Chvi	5.2	4.3	.9659
Orhy	1.7	1.5	.9971
Eriog[1/]	2.7	.6	.7974[1/]
Phdi	1.5	1.3	.9953

Inside	1968 Field % cover	1968 Photo % cover	
Arno	11.1	13.4	.9215
Eula	3.1	2.4	.9856
Chvi	4.0	3.7	.8788
Orhy	1.2	.6	.8525
Eriog	2.4	1.8	.5626
Phlox	.5	.4	.9442
Total	23.4	22.6	.9585

Inside	1968 Field density	1968 Photo density	
Arno	6.1	7.1	.8929
Eula	4.6	4.2	.956
Chvi	4.3	3.8	.975
Orhy	3.1	2.4	.944
Eriog	2.6	1.7	.9093
Phlox	7.7	7.5	.7750

1/ *Eriogonum* is not significant (P> .05) because it is a very small plant which cannot be distinguished from *Arno* because it is very near the same color.

2/ P< .05 for all correlation coefficients.

Arno - Artemisia nova; Eula - Eurotia lanata; Chvi - Chrysothamnus viscidiflorus; Orhy - Oryzopsis hymenoides; Eriog - Eriogonum sp.; *Phdi= Phlox diffusa*

Table 6. Correlation coefficients between field and photo percent cover and density at Mormon Mesa.

	Field % cover	Photo % cover	Correlation coefficient
Amdu	5.2	5	.9881[1/]
Hiri	.7	1.1	.9292
Latr	4.0	3.5	.994
Krpa	.9	.7	.9915
Eula	.9	.7	.9628
TOTAL	11.9	11.2	.9835
	Field density	Photo density	
Amdu	1.7	1.7	1.000
Hiri	2.2	2.1	.9644
Latr	.3	.3	1.000
Krpa	.2	.2	1.000
Eula	.2	.2	1.000
TOTAL	4.8	4.7	.9887

[1/] P<.05 for all correlation coefficients.
Amdu - Ambrosia dumosa; Hiri - Hilaria rigida; Latr - Larrea tridentata; Krpa - Krameria parvifolia; Eula - Erotia lanata.

Table 7. Correlation coefficients between field and photo percent cover and density at Doby Summit.

	1968 Field % cover	1968 Photo % cover	Correlation coefficient
Arlo	22.1	20.7	.928[2/]
Chvi	3.9	4.0	.9796
Feid[1/]	1.0	.9	.8517
TOTAL	27.3	25.9	.9363
	1968 Field density	1968 Photo density	
Arlo	8.4	8.6	.9364
Chvi	1.6	1.8	.9628
Feid[1/]	6.6	3.7	.8372
	1968 Field % cover	1968 Photo % cover	
Arlo	22.1	25.6	.9494
Chvi	3.9	4.8	.9718
Feid[1/]	1.0	.4	.5767[1/]
TOTAL	27.3	30.9	.9553
	1968 Field density	1968 Photo density	
Arlo	8.4	8.7	.7368
Chvi	1.6	1.6	.9947
Feid[1/]	6.6	3.6	.6927[1/]
TOTAL	17.1	14.4	.7417

1/ The correlation coefficients were not statistically significant ($P > .05$) for *Feid* because nearly all of the plants were located beneath *Arlo* plants making them very difficult to locate.

2/ $P > .05$ for all correlation coefficients.

Arlo - Artemisia longiloba; Chvi - Chrysothamnus viscidiflorus; Feid - Festuca idahoensis

large shrubs and were not visible on the photos for measurement. The base of visible grass plants was usually concealed by top growth when not grazed.

Correlation coefficients between field and photo data for density (plants/unit area) were high for most species. Correlation was often low for species of *Artemisia* due to the difficulty of determining whether one or two or more plants were growing in a single clump. Correlation was low for most grasses. Many grass plants were not counted because they were not visible on the photos.

Phenology was an important photo interpretation criterion due to changes in the appearance of plants at different times of the year. For example, rabbitbrush was often difficult to differentiate from black sagebrush at Major's Exclosure in 1968 when neither plant was in bloom. In 1969, rabbitbrush, in full bloom, was easily differentiated from black sagebrush by its bright yellow flowers. Rabbitbrush plants in full bloom appeared larger on the photos when compared to the same plant not in bloom. Results seem to support this observation as a greater percent cover of rabbitbrush was recorded in 1969 during full bloom than in 1968 when not in full bloom.

The time required for two men to set up the equipment, snap a stereo pair, disassemble the equipment and move on was about 10 minutes. If a species list and map of the photo plot were desired, considerably more time would be required depending on the complexity of the vegetation and the number of measurements desired.

Considerable field time was saved by the photographic technique even though additional office time was required. The office time varied with complexity of the vegetation, but an average of 10 minutes was required to planimeter all plants on mylar overlays for each stereo pair after the equipment was initially set up. These overlays were placed on graph paper for computing the area of each species. This took an average of 14 minutes per stereo pair. Next, the percent of the plot covered by each species was computed from the scale. Scale was computed on each site because printing was not always the same. Density was found by counting the plants planimetered on the mylar overlay. These last two operations required 10 minutes, making a total office time of 35 minutes per stereo pair (Table 8).

We find it problematical whether data obtained from only 2 or 3 plots per key area would provide similarly high correlation coefficients. This would depend a great deal on the homogeneity of the vegetation as viewed in a 5-by-5 foot plot. A few plots in a key area may or may not provide accurate trend determinations. For this reason, 70mm large scale aerial photography appears to have promise, since larger samples are obtained in a similar time and cost framework.

70mm Aerial Photography

Detailed notes were made for each species visible on all sites on both color and color infrared (IR) films. Not all species were readily

Table 8. Summary of time requirements for computing both cover and density in the office and the field time for one 5-ft^2 plot (one stereo pair).

Operation	Time involved (Minutes)
Planimeter	10
Count squares	15
Summarize	10
Office total	35
Field total[1/]	10
Field method[2/]	45

1/ The field total reflects the time required for two men to set up the equipment, snap a stereo pair, disassemble the equipment and be ready to move on. If a map or species list is desired, it will take longer.

2/ The time required to gather the data by the BLM field procedure per plot.

identified. Those species identified with some regularity were included in interpretive keys. Other species were often visible, but could not be identified.

Species identification tests were devised that contributed invaluable characteristics to species identification keys. Where possible, more than one characteristic was included to aid interpretation. Due to variability within a species, one characteristic may not hold true for every individual. The interpreter must consider all differentiating characteristics before a final decision is made. Dichotomous photo interpretation keys for several study sites are presented in Appendix A.

The planimeter method (Table 9) was considered the most accurate cover method. This method measured the total area of every plant within a specified boundary. Similar results were obtained on aerial photographs as in the field. Considerably larger areas were sampled than by the field method in a significantly shorter time. As an example, approximately 12 hours were required to obtain cover data for all important species in the field excluding travel to and from the Mormon Mesa site. The same results were obtained from the photographs in 90 minutes, excluding aircraft travel time.

The point method yielded results similar to those obtained in the field and was faster than the planimeter method (Table 9). Only a few minutes were required, for example, to obtain results similar to those obtained in the field. The same photographs were sampled several times to see if results could be duplicated. An important question was whether a second interpreter could arrive at the same conclusion. A second interpreter, who had no experience with 70mm photographs, used this method to arrive at a percent cover on bitterbrush at the Paine Springs site (Fig. 5) nearly identical to that obtained by the field method (Table 9). This was attempted on both prints and transparencies with similar results. For relatively reliable results, the point and estimation method appeared to have considerable merit for quickly extracting cover data of the prominent species from 70mm aerial photography.

The estimated time and projected costs of collecting data by the field method and the 70mm aerial photographic method are contrasted. Thirty minutes of aerial flight time at $20 ($40 per hour) are estimated for each site. Ten feet of film at $10 for purchase and development is estimated to be sufficient. The total cost is then $30 or 60 cents for each exposed frame excluding the salary of the camera operator and pilot.

Office time is estimated at 1 hour to obtain the cover and density of the major species on a stereo pair. This includes time for identification of visible species using the point method to obtain cover.

The field method required approximately one full working day for two persons to obtain cover and density of all species on a site. This includes little or no travel time to and from the site. Summarization of the data in the office required an additional 5 hours per site for one person.

To summarize, if travel time is excluded, one man-hour is required to extract data from aerial photographs, and about 20 man-hours are required for the field procedure. The aerial photographic procedure does not, however, include all species while the field method does. Where specific sample areas were delineated on the aerial photographs, they were from two to ten times the size of those used in the field (Table 9).

Table 9. Percent cover for the cover methods indicated at the Paine Springs, Mormon Mesa and Ward Mountain site.

Site and Method	Species				Sample Size -ft² or no. of points	Time -min.-
	Amdu	*Hiri*	*Krpa*	*Latr*		
Mormon Mesa						
field method	3.1	.8	.7	3.3	500	660
planimeter[p]	3.6	1.1	1.5		1,195	60
planimeter[p]				3.2	4,475	30
point method[p]	5.2	1.0	2.8	4.2	1,012 pts.	45
point method[p]	4.7	1.4	1.4	3.7	1,024 pts.	30
point method[t]	4.9	.7	1.8	3.0	550 pts.	20
estimate method[p]	3.6		1.3		1,523	30
estimate method[p]				3.7	3,047	15
Paine Springs	*Artr* & *Teca*		*Putr*			
field method	21.2		13.5		250	420
planimeter[p]	21.0				3,072	90
planimeter[p]			14.5		5,549	90
planimeter[p]	22.1				1,908	60
planimeter[p]			13.9		4,240	60
point method[p]			14.0		1,024 pts.	20
point method[p]	23.0				512 pts.	15
point method[p]	23.0				225 pts.	10
point method[p]			14.5		144 pts.	7
point method[p]			14.9		268 pts.	15
point method[t-*]			13.2		99 pts.	15
point method[t]			14.5		330 pts.	15
point method[p]	22.1				280 pts.	10
point method[t]	24.0		13.2		440 pts.	20
estimate method[p]	18.6				1,960	45
estimate method[p]	23.0				1,103	30
estimate method[p]	24.9		15.9		2,346	90
estimate method[p]			17.0		2,962	60
estimate method[p]			13.0		2,943	60

(continued)

ble 9. Continued

Site and Method	Species Arno	Sample Size -ft² or no. of points	Time -min.-
Ward Mountain			
field method	22.9	75	60
estimate method[p]	22.0	5,886	30
point method[p]	24.0	240 pts.	10

p = prints; t = transparencies; * = another interpreter;
Amdu - Ambrosia dumosa; Hiri - Hilaria rigida; Krpa - Krameria parvifolia; Latr - Larrea tridentata; Artr - Artemisia tridentata; Putr - Purshia tridentata; Teca - Tetradymia canescens; Arno - Artemisia nova.

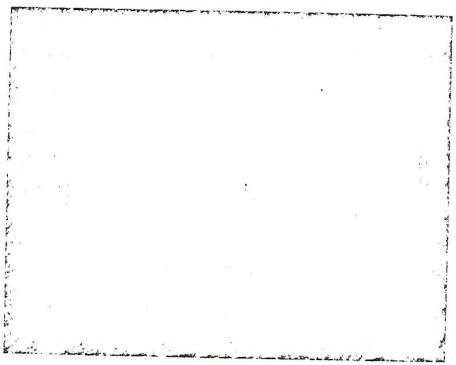


Fig. 5. Color infrared print of Paine Springs showing bitterbrush (1), big sagebrush (2), rabbitbrush (3) and bunchgrass (4). Marker (8-ft x 1 ft)at (a) was used to compute scale.

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APPENDIX A

Dichotomous species identification keys for 70mm low-level, large scale aerial photography.

Doby Summit

Artemisia longiloba/Festuca idahoensis

1. Plants shrubs, appear larger.

   2. Plants with irregular pattern and coarse texture; margins of plants very irregular; blue gray on color and deep bluish green on color IR (August 18, 1969); stems visible to give interior portions of plants a dark appearance ----------
   ----------*Artemisia longiloba*

   2. Plants with irregular pattern, but slightly more uniform than *Artemisia longiloba* and medium texture; margins of plants irregular, but not quite as much as *Artemisia longiloba*; dark stems not visible within plant; deep yellow on color due to flowers showing (August 18, 1969) and deep red orange on color IR (August 18, 1969)----------
   ----------*Chrysothamnus viscidiflorus*

1. Plants grasses or forbs, appear very small.

   3. Plants with uniform pattern and fine texture; appear as small, puffy balls; plants very light bluish green on color and intermediate purplish pink on color IR (June 22, 1969); these plants were not visible later in the season ---------
   ----------*Lupinus* sp.

   3. Plants with uniform pattern and fine texture; appear as small, puffy ball; pale greenish yellow on color and pinkish white on color IR (June 22, 1969); these plants were not visible later in the season ----------
   ----------*Festuca idahoensis*

Secret Pass

Amelanchier pallida/Artemisia tridentata/Symphoricarpos longiflorus

1. Plants large shrubs

   2. Plants usually very large shrubs in terms of area and height; large, loose, clumpy pattern with coarse texture; some white stems are visible in the middle of the plant; medium olive green to medium yellow green on color and solid red on color IR with some darker red patches within the plant on both May 27, 1969 and June 22, 1969 ------*Amelanchier alnifolia*

2. Plants medium-sized shrubs; may cover considerable area, but are not very tall; otherwise not as above.

3. Plants large, spreading, low-growing with uniform pattern and medium texture; usually found growing beneath and around *Amelanchier alnifolia*; solid yellow green on color and very red on color IR (June 22, 1969) ----------*Symphoricarpos longiflorus*

3. Plants not large and spreading, but usually have single stems; no apparent pattern and medium texture; can often see dark stems within the plant; pale yellow green on color and gray purplish red on color IR (June 22, 1969)----------*Artemisia tridentata*

1. Plants very small shrubs, forbs or grasses.

4. Plants with conspicuous flowers.

5. Bright yellow flowers conspicuous on June 22, 1969 photographs; leaves mostly inconspicuous, but a few may be visible as basal rosette; flowers appear as white, puffy ball on color IR ----------*Crepis acuminata*

5. Bright yellow flowers conspicuous on May 27, 1969 photographs; leaves appear with medium, tight, clumpy pattern and very uniform texture; small *Artemisia tridentata* may appear similar if yellow flowers are not visible (June 22, 1969), but this plant has a whitish cast to the leaves; flowers appear white on color IR; flowers appear as white, puffy ball on June 22, 1969, due to the presence of seed heads; leaves are pale yellow green on color and dark purplish pink on color IR ----------*Balsamorhiza sagittata*

4. Plants without conspicuous flowers.

6. Plants large bunchgrasses appearing to radiate outward from a central point with medium texture rays; medium olive green on color and solid red on color IR (June 22, 1969) ----------*Elymus cinereus*

6. Plants usually smaller than above; small shrubs; uniform pattern with fine texture; medium olive green on color and deep red on color IR (June 22, 1969) ----------*Chrysothamnus viscidiflorus*

Ward Mountain

Pinus monophylla/Juniperus osteosperma/Artemisia nova

1. Plants trees; bright red on color IR.

2. Plants with large, loose, clumpy pattern and fine texture, top usually rounded; light olive on color and solid pink on color IR----------*Juniperus osteosperma*

2. Plants with no apparent pattern and coarse texture; top of plant many times pointed; white branches visible within plant; dark olive on color and solid red on color IR -----
----------*Pinus monophylla*

1. Plants shrubs; dull red or dark red on color IR.

3. Plants with medium, loose, clumpy pattern and medium texture; small shrubs; dark stems and shadows visible between the clumps; casts small, somewhat irregular shadow; blue gray on color and dark red clumps on color IR (July 28, 1968); plants grow in the openings between the trees ----------
----------*Artemisia nova*

3. Plants with no apparent pattern and medium texture; usually a little larger than *Artemisia nova*; casts larger, more solid shadow; blue gray on color and intermediate pink on color IR (July 28, 1968)-------*Purshia tridentata*

Mormon Mesa

Yucca brevifolia/Larrea tridentata

1. Plants trees or tree-like; light yellow greeen on color and deep pink on color IR (July 20, 1968)----------
----------*Yucca brevifolia*

1. Plants smaller; grasses, forbs or shrubs.

2. Plants shrubs.

3. Plants large shrubs with small, loose, clumpy pattern and coarse texture; plants are widely, but rather evenly distributed; foliage within plant is loose and sparse; shadow is large, sparse and rounded; difficult to distinguish edge of plant from shadow; dark olive on color and deep red on color IR (July 20, 1968) ----------
----------*Larrea tridentata*

3. Plants medium or small shrubs; cast a medium-sized, dense shadow; foliage within plant is not loose and sparse.

4. Plants with medium, tight, clumpy pattern and medium texture; medium-sized shrubs, but fairly tall; usually on single stems with the base free of foliage; light greenish yellow on color and very pale purple on color IR (July 20, 1968)----------
----------*Opuntia* sp.

4. Plants with uniform pattern and medium texture; plants round or oval with slightly irregular margins; plants otherwise not as above; dark stems visible within the plant; plants cast dense shadows.

5. Plants greenish gray on color and intermingled dark gray and black on color IR (July 20, 1968)---------- *Ambrosia dumosa*

5. Plants very dark greenish blue on color and deep red on color IR (July 20, 1968) ---------- *Krameria parvifolia*

2. Plants smaller, grasses or forbs.

6. Plants appear to radiate outward from center; rays have medium texture; pale greenish yellow on color and dark gray and black intermingled on color IR (July 20, 1968) ---------- *Hilaria rigida*

6. Plants radiate out from central stem with one to several rays; rays with very coarse texture; light grayish white on color and very light green on color IR (July 20, 1968) ---------- *Eurotia lanata*

Palne Springs

Purshia tridentata/Artemisia tridentata/Agropyron spicatum

1. Plants trees.

2. Plants with large, loose, clumpy pattern and fine texture; top usually rounded; dark greenish yellow on color and solid red on color IR (July 30, 1968)---------- *Juniperus osteosperma*

2. Plants with no apparent pattern and coarse texture; top many times pointed; plants may be seedlings on this site and exhibit much finer texture, but can be recognized very easily by color; light blue green on color and solid red on color IR (July 30, 1968)---------- *Pinus monophylla*

1. Plants not trees.

3. Plants grasses; center of plant black or nearly black with fine texture rays radiating out from the center; intermediate yellow on color and pale pink on color IR (July 30, 1968) ---------- *Stipa comata* and *Agropyron spicatum*

4. Plants pink on color IR; no apparent pattern with medium texture; medium-sized shrubs; very light bluish greeen on color and pale pink on color IR (July 30, 1968) --------- *Purshia tridentata*

5. Plants with uniform pattern and fine texture; small shrub; more sparse than *Purshia tridentata*; medium olive on color and deep red on color IR (July 30, 1968); can be readily identified on August 29, 1969, by its bright yellow flowers----------*Chrysothamnus viscidiflorus*

Duck Creek Basin

Cercocarpus ledifolius/Symphoricarpos longiflorus

1. Plants trees.

2. Plants with no definite pattern and coarse texture; many white stems visible within the plant; may have pointed top; dark olive on color and solid red on color IR----------*Pinus monophylla*

2. Plants with clumpy pattern; few or no white stems showing; otherwise not as above.

3. Plants with large, loose, clumpy pattern and fine texture; top usually rounded; no white stems visible, light olive on color and deep pink on color IR----------*Juniperus osteosperma*

3. Plants with large, loose, clumpy pattern and coarse texture; stems radiate out from a central point within each clump; few white stems visible; dark gray olive green on color and very red on color IR----------*Cercocarpus ledifolius*

1. Plants shrubs.

4. Plants very large shrubs growing in large clumps; dark stems visible within the plant; light olive brown on color and dark red on color IR (July 20, 1968)----------*Ephedra viridis*

4. Plants medium-sized shrubs; grow more scattered; otherwise not as above.

5. Plants light bluish gray on color and intermediate pink on color IR (July 20, 1968)----------*Artemisia tridentata*

5. Plants dark green on color and solid red on color IR (July 20, 1968)----------*Symphoricarpos longiflorus*

General key. All species from all sites were combined in one key. Several characteristics were used to separate similar species on different sites that did not appear together in the individual key. A few of the same species were present on more than one site. They may appear slightly different on various sites due to different environmental influences so slightly more encompassing characteristics were developed to adequately group these species. A general key for Doby Summit, Secret Pass, Ward Mountain, Mormon Mesa, Paine Springs and Duck Creek Basin sites can be found in Lorain (1970).

APPENDIX B

FREQUENCY SAMPLING PROCEDURES FOR
DETERMINING THE TREND OF RANGE VEGETATION

(3rd Approximation)

Frequency sampling is proposed as a rapid, objective means of evaluating the trend of range vegetation. Theoretically, yearly production or yield data corrected to a median year would provide the best test for trend. Such data, however, is difficult and expensive to obtain. Cover or density (plants/unit area) data may also be very valuable parameters for the evaluation of vegetation trend. These latter two methods likewise tend to be expensive. Frequency data historically have been correlated with all three types of data and especially with density data. In attempts to use some of these methods there has been a tendency to use estimation techniques with a high degree of subjectivity. Such methods are difficult to duplicate.

On the other hand, frequency sampling involving a determination of species presence is completely objective and very easy to duplicate from year to year by the same or different technicians. We are hopeful that this method will be capable of exact duplication when final summaries are in the hands of range managers about to make grazing management decisions.

Frequency sampling has two important advantages over other previously used methods. One, the method is highly objective, with a minimum amount of human decision involved, and two, it is relatively simple and easy to perform. Human decision is limited to whether the plant is rooted within the frame or not and to species identification. Frequency sampling is economical in terms of time because the average sample takes less than one man-hour to establish and read.

Presently, the frequency sampling method provides trend of change in vegetation composition exclusively. There have been no definite condition classes established, although a study of that nature is currently being pursued and should soon be completed for several habitat types. Meaningful condition classes can be developed only after the accumulation of considerable empirical data.

1. Selecting the Representative Site.

The most important factor in the determination of the trend of range vegetation is the recognition of site potential. Successful trend evaluations are completely dependent upon an adequate synecological understanding of the range landscape.

Trend plots must be placed in what are recognized as homogeneous stands representative of specific "habitat types" that occur in space and time. One must be fully aware of and understand the fact that upon placement of a trend plot that it is only representative of sites with similar potential.

The term "habitat type" was coined by Daubenmire and can be defined as follows, "the collective area which is capable of supporting the same relatively homogeneous climax plant association." Poulton furthers this definition by proposing that "a habitat type denotes an ultimate unit of the sum environment," and that "these basic units constitute the basic subdivisions of the landscape for management purposes." In these definitions, soils are considered a part of the habitat type.

In many instances, certain "habitat types" will be of special value on grazing types and should be carefully evaluated for vegetation change. On the contrary, other habitat types occur infrequently or have little value as grazing types or both. These habitat types probably will not justify intensive sampling. Each of the important habitat types should be included. This concept is somewhat similar to that of the "key area," however, there is one important difference. With the "key area" concept, we consider that all the range is exhibiting trends similar to the area evaluated. With stratification by "habitat type," we are assuming that this is not true.

Site potential can be defined or described by considering some or all of the following criteria:

A. Dominant species
B. Soil and soil characteristics
    1. depth
    2. pH
    3. Texture of surface horizon
    4. Color of surface horizon
    5. Horizon sequence
    6. Texture of B2
    7. Color of B2
    8. Presence or absence of a restricted layer
    9. Drainage
    10. Organic matter and cation exchange capacity of the surface horizon
C. Aspect of exposure
D. Elevation
E. Land form
F. Precipitation
G. Production - this factor can often be highly correlated with other vegetation criteria such as cover, density (plants/unit area) and frequency of occurrence.

There is no need for each of the above items to be evaluated at each site. They are listed as items that have been used to help describe site potential and one, several, or all of them may help evaluate the importance of a given "habitat type."

We must make the assumption that within a "similar management unit," a given habitat type will possess the same condition at a given time. A "similar management unit" may be represented as a fenced area, a drainage, a range in close proximity to water, a range far from water, a seeded area. or what have you.

After a training period, plot locations can be established. Theoretically, if the synecology and site potential were completely understood it would be possible to rely on one frequency sample per important habitat type. Other habitat types are so unimportant that they would require no quantitative samples. Since the theoretical is rarely attained, perhaps it would be well to place two or three samples in representative stands of important habitat types found within "similar management units." The value of the range and the time and resources available will have to dictate sampling intensity.

II. Sampling procedures

A. Tools - The tools required for collecting frequency data are quite simple:
   1. 100 ft tape
   2. Two surveying pins
   3. Two rebars and hammer
   4. One to three rebars to be placed as an aid to plot relocation
   5. Frequency frames
   6. Clip board
   7. Forms
   8. Tally counter

A set of frequency frames which have sizes ranging from 30-inches square to 3-inches square is necessary. These frames should be light weight but sturdy. They should be made with one open side to facilitate proper placement - a section of strap metal opposite the open side with steel rods forming the other two sides. Short prongs placed at the proper intervals along the strap metal and protruding into the center of the frame and parallel to the sides will provide nested frequency frames of smaller sizes. Each frame should have a 3-foot handle to facilitate handling ease. It is convenient to have a 30-, 20-, 15-, 12-, 10-, 6- and 3-inch frame available. These different sizes can be nested easily into three tools. The 30-inch and 15-inch frames fit together. The 20-inch and 10-inch frames nest well and the 12-inch, 6-inch and 3-inch frames nest into one implement. We hope that two or three basic frame sizes will suffice for efficient sampling of all important habitat types in Nevada.

In addition to the frames, one 100-ft steel tape is needed. A spring with a swivel on it is useful for keeping this tape tight and straight while it is in use. Surveying pins are useful for securing the baseline tape.

Stakes for marking the permanent study area can be made from reinforcement bar (rebars). They should be painted a brilliant color to insure their relocation from year to year. A stake-driving hammer is necessary also.

To record the data, a clip board and proper field forms are needed. A tally counter is useful for keeping the proper number of quadrats per transect.

B. Plot layout

The first step in establishing a condition and trend study plot using requency sampling is laying out the baseline (Fig. 1). This line constitutes the permanent portion of the frequency trend plot. The line is estabblished by stretching a 100-foot steel tape in a representative portion of the habitat type to be evaluated. The tape is stretched as close to the ground as possible and affixed to the ground with 2 surveying pins.

Each baseline will be placed on the contour. If the plot is to be placed on the level then it will be oriented to the north and south. For relocation purposes, it would be good to draw a map on the back of the summary sheet that is numbered and dated correctly. The map will show roads, trails, distinguishing topographic features, trees, rocks, and related items and will be used as a means of returning to the baseline. A rebar placed near the road at a given distance from a known point will be helpful in relocation. This rebar will then be used to measure out to and find one end of the baseline. Relocation of the baseline is of paramount importance.

The second step consists of selecting the appropriate frame size and the recommended transect/quadrat allocation. This latter term we have chosen to refer to as "the simple plan." Prior evaluations on the important range plant communities or habitat types in Nevada have indicated the most efficient frame sizes and sample plans (Table 1). In some instances, dual sampling using two frame sizes, a smaller one for very abundant species, has been recommended. These guides have been developed to give the best possible sample for the greatest number of species on any given habitat type. Efficiency was evaluated in terms of data variance and cost (time spent in sampling).

Transects consists of groups of quadrats (presence or absence frames) placed contiguously or at given intervals. At present, we are recommending contiguous placement, i.e., a belt transect. The sampler can accomplish this by keeping a mental record of the location of each corner of the frame and then placing the right hand corners where the left hand corners had been previously. This procedure will be reversed if the transect is started in the opposite direction. Each transect is originated at a random footmark along the baseline. The randomization is restricted so that five transects are randomized on each side of the 50-foot mark. Ten and 20 random numbers and directions are listed below.

Twenty Random Foot Marks

1.	2D	11.	52U
2.	7U	12.	54U
3.	17U	13.	61D
4.	20U	14.	62D
5.	25U	15.	69D
6.	29D	16.	77D
7.	37D	17.	80D
8.	40U	18.	81U
9.	42U	19.	85D
10.	45D	20.	98U

Ten Ramdom Foot Marks

1.	2D	6.	52U
2.	17U	7.	61D
3.	25U	8.	69D
4.	37D	9.	80D
5.	42U	10.	85D

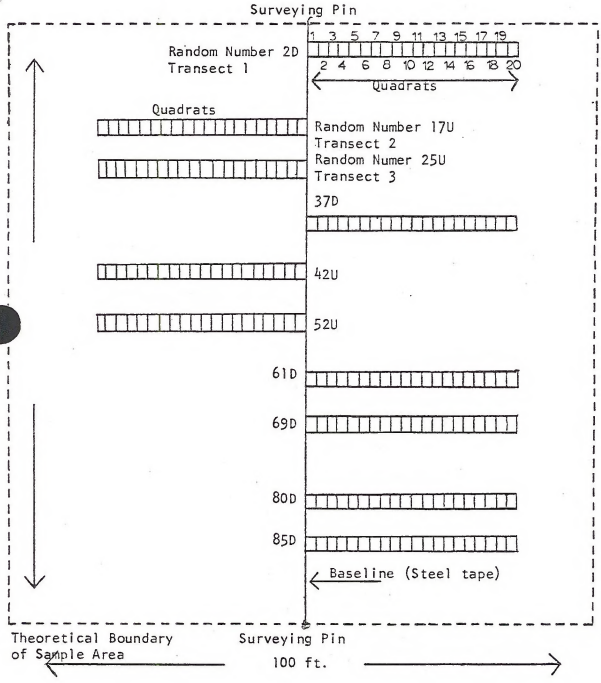

Fig. 1. Schematic Outline of a Macroplot
Sample Plan = 10 Transects of 20 Quadrats (10/20)

Using 20-inch frame the outline would be to scale.

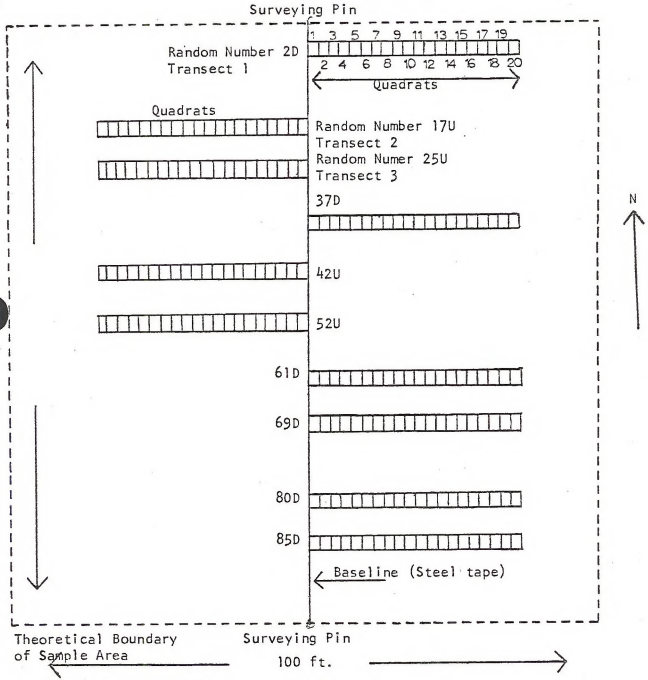

Fig. 1. Schematic Outline of a Macroplot
Sample Plan = 10 Transects of 20 Quadrats (10/20)
Using 20-inch frame the outline would be to scale.

Table 1. Appropriate frame sizes and sample plans (transect-quadrat allocations) for efficient sampling of certain range plant communities in Nevada.

Plant Community	Frame size Recommendation	Transect-quadrat allocation***
1. *Artemisia tridentata/Oryzopsis hymenoides*	30"*	20/20
2. *Artemisia tridentata/* (Seral)	16"	10/20
3. *Artemisia nova/Poa secunda*	20"(10")**	20/10
4. *Artemisia arbuscula/Poa secunda/ Agropyron spicatum*	10"	20/10
5. *Eurotia lanata*	3"	20/10
6. *Sarcobatus baileyi/Oryzopsis hymenoides*	12"	20/10
7. *Chrysothamnus viscidiflorus/*	6"	20/10
8. *Artemisia spinescens/Atriplex confertifolia*	10"	20/10
9. *Artemisia arbuscula/Bromus tectorum*	24"(3")	20/10
10. *Artemisia longiloba/Poa secunda/Festuca idahoensis*	24" or 30"(15")	20/20

* The length of one side of a square quadrat

** For *Artemisia nova* only

*** The most efficient ratio of transects to quadrats
3" - *Bromus tectorum*
15" - *Artemisia longiloba, Phlox diffusa, Poa secunda*

U = Up the hill or west on plots oriented north & south

D = Down the hill or east on plots oriented north & south

Transects are constructed by placing a selected number of quadrats side by side in a line perpendicular to the baseline. When the frequency frame is placed on the ground it forms one quadrat. When it is lifted and placed immediately adjacent to the established quadrat, a transect is started. Continuation of this procedure through 10 or 20 quadrats will constitute a transect. Once a transect is complete, the worker moves to the next random foot mark and starts again.

The presence or absence of a species is dependent upon its root location - - rooted frequency. If any part of a plant is rooted inside the frame it is counted as being present. There is one exception, the mountain brush types. Preliminary studies indicate the possible need to use canopy frequency presences.

Reading the quadrats consists of two very simple decisions. If a plant is rooted in the quadrat and the worker can recognize the species, then its presence should be recorded. Plants which are unknown should be marked with a symbol for later identification. Careful observation of the quadrat will show the species rooted within. Only one hit per species is recorded regardless of the number of individuals occurring within the quadrat. The examiner can speed up the data collection process by reading the number of each quadrat before he reads the species present (i.e., quadrat one - *Artr, Agsp, Arsp* - - quadrat two - *Artr, agsp, Pose* - - etc.).

The hits can be recorded by the simple point-line method. This procedure employs 4 dots in a square with six lines connecting the dots forming a box with an "X" across its surface. This gives 10 marks for records of hits; if more than 10 hits are recorded a second box can be constructed. A multiple tally counter is still in the experimental stage.

Field Frequency Data Sheets and Trend Summary Forms are attached to these procedures. Habitat type, location, plot number, examiner, recorder, date, sample plan, frame size, interval (when appropriate), sheet number, all species, notes, etc. should be recorded. The percent frequency can be computed very simply by multiplying the number of hits or presences by 10 if there are 10 quadrats and by 5 if there are 20 quadrats.

As a rule of thumb, it is expected that all frequency percentages for important species should fall between 10 and 90 percent or if possible between 20 and 80 percent. This will provide the greatest possible chance of detecting an important trend for a species when the plot is read again. Technicians should strive to use a frame size that will produce numbers falling in this range for the greatest number of species.

C. Summarization

All frequency data should be converted to percentages and to mean frequencies per 10 or 20 transects. Electronic Data Processing programs

Procedure Summary

1. Place the baseline in a representative stand of an important habitat type. Make provisions for its relocation.

2. Select the appropriate frame size and recommended sample plan for the habitat type in question.

3. Read and record quadrat data for each randomly located transect.

4. Hits are recorded only when the species is rooted within the quadrat.

5. Only one hit is recorded per species and per quadrat regardless of the number of individuals occurring within the frame.

6. Record frequency percentages by species and place value on data pads ready for computation.

3rd Approximation

Field Frequency Data Sheet

Habitat type: _____ Examiner & Recorder _____ Date _____ Site No. _____ Frame size _____

Location _____ Sample Plan _____ Interval _____ Sheet No. _____

Species	Trans. No.	%	Trans. No.	%	Trans. No.	%	Trans. No.	%	Trans. No.	%	Trans. No.	%	Trans. No.	%	Trans. No.	%	Trans. No.	%

2nd Approximation

TREND SUMMARY

Habitat Type_____ Location_____ Site No._____

Sample Plan_____ Frame size_____ Interval_____

Initial Evaluation: Yes__ No__ Change of Frame_____ * Date_____

Species	Percent Frequency 'Date___ 'Date___ 'Date___ 'Date___ 'Date___	Percent change by period	Trend Index

*Notes_____